Water Footprint For Pulse, Cereal, And Oilseed Crops In Saskatchewan

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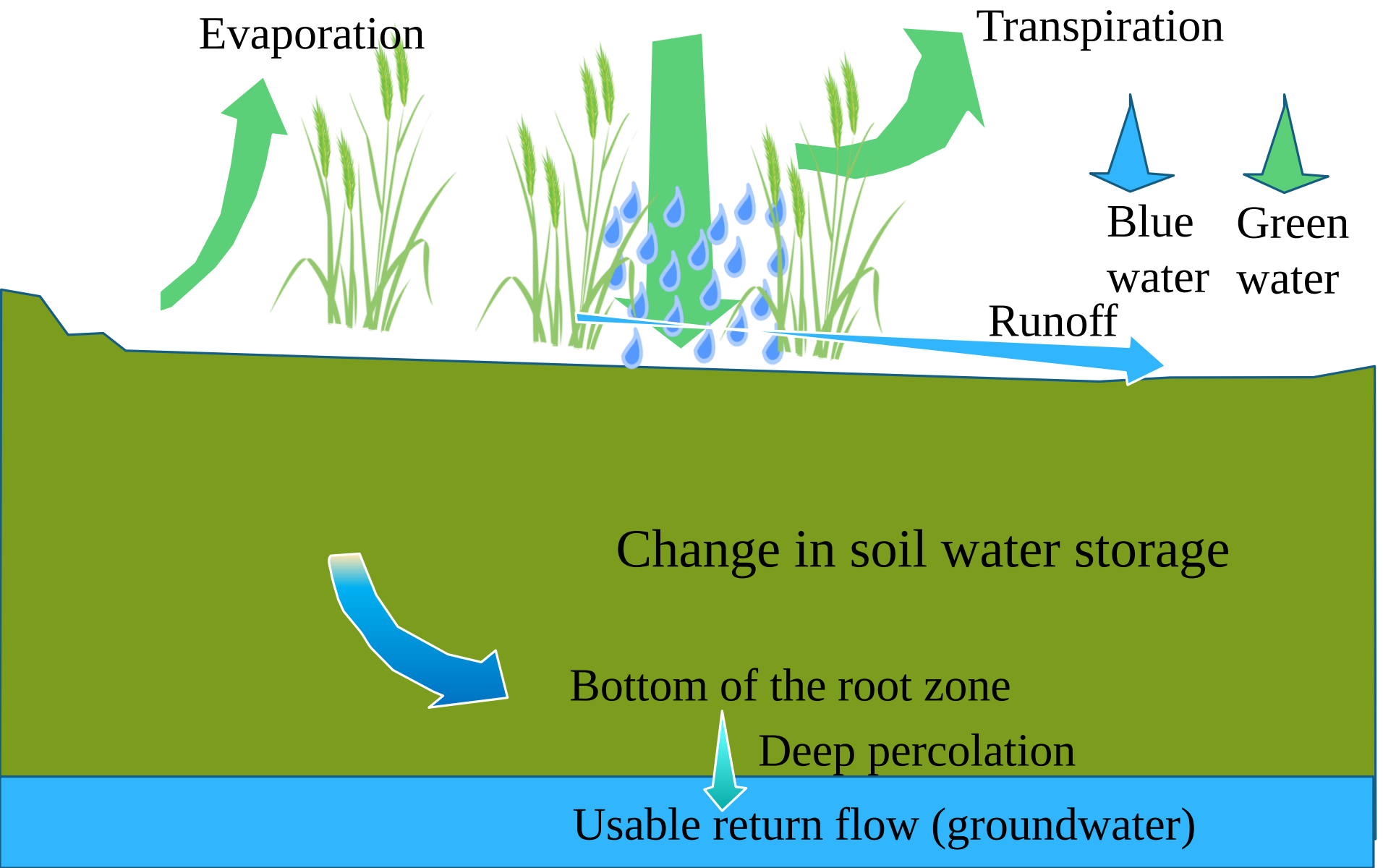
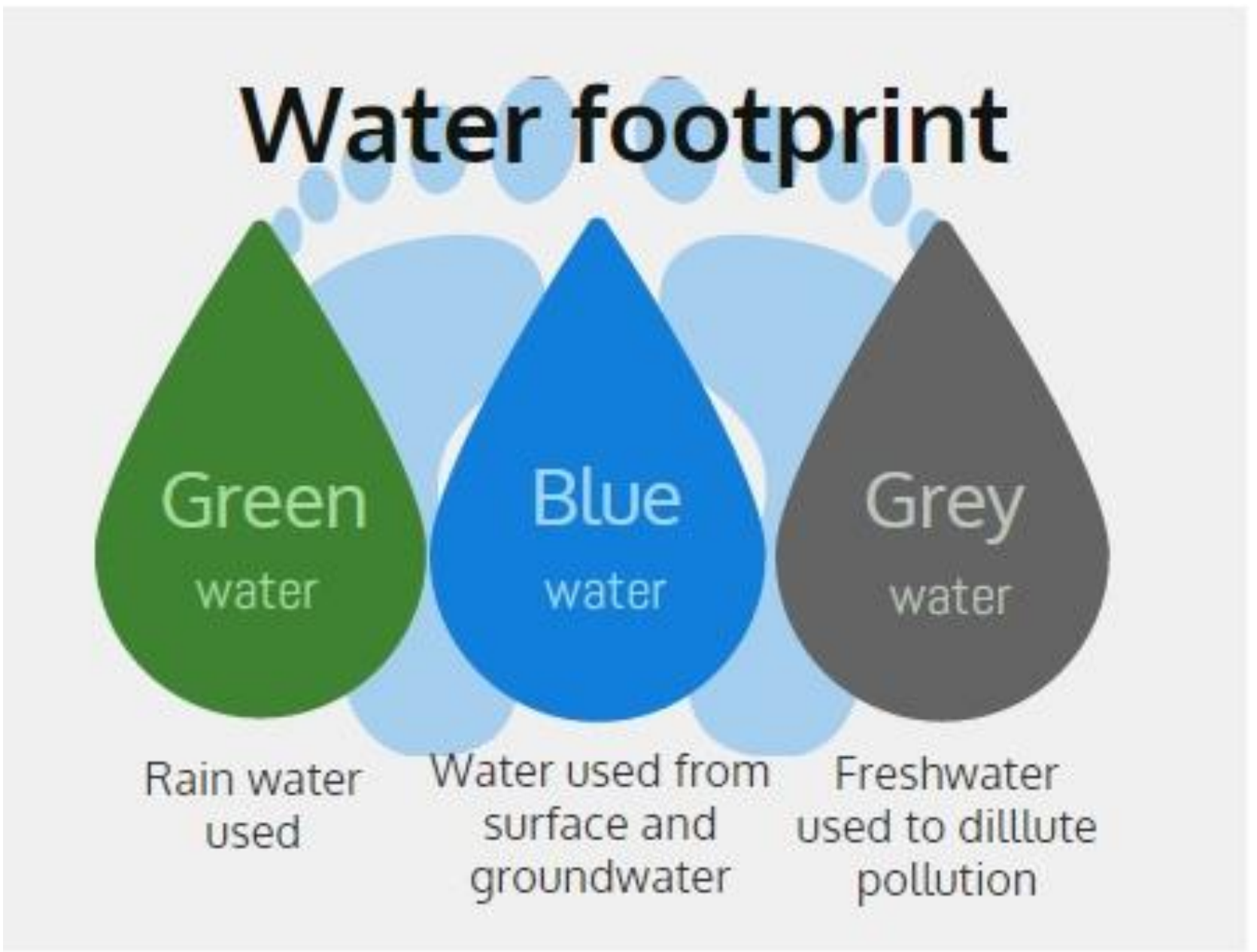
Introduction

- **Pulse cropping**
  - Provides excellent income opportunities for growers
  - Provide healthy diets to consumers
  - Meet the global demand for protein
- **Cereals have a high carbon footprint**
  - Cereals are usually grown with added human-made nitrogen at around 110 kg N per hectare.
  - Artificial nitrogen comes from fossil fuels
- **Rotation with pulses incorporated**
  - Legumes fix their own nitrogen.
  - When grown with other crops such as barley, the pulses supply the cereal's nitrogen needs

The Fate Of Precipitation




Water footprint
Green
water
Blue
water
Grey
water
Rain water used
Water used from surface and groundwater
Freshwater used to dilllute pollution

Why Water Footprint?

- **Measure of water productivity**:

$$WUE = \frac{Grain\ or\ seed\ yield}{Water\ applied\ to\ the\ field}\ (kg\ ha^{-1}cm^{-1})$$

- **Water footprint is the reciprocal of, but more general than, the WUE**
  - The water footprint within a province or river basin is equal to the sum of the water footprints of all processes taking place in that area

Water Footprint Of A Product

- **Green water footprint**
  - **volume of rainwater evaporated**
- **Blue water footprint**
  - **volume of surface or groundwater evaporated**
- **Grey water footprint**
  - **volume of polluted water**
- **By reducing WFs, we utilize our precious water resources more effectively**

Objectives

- **The objective is to evaluate the long-term crop WFs in Saskatchewan over the past five decades**
  - Compare pulse crops with cereals in terms of WF
  - Identify the factors that contributed to the difference in WFs of different crops

Study Area

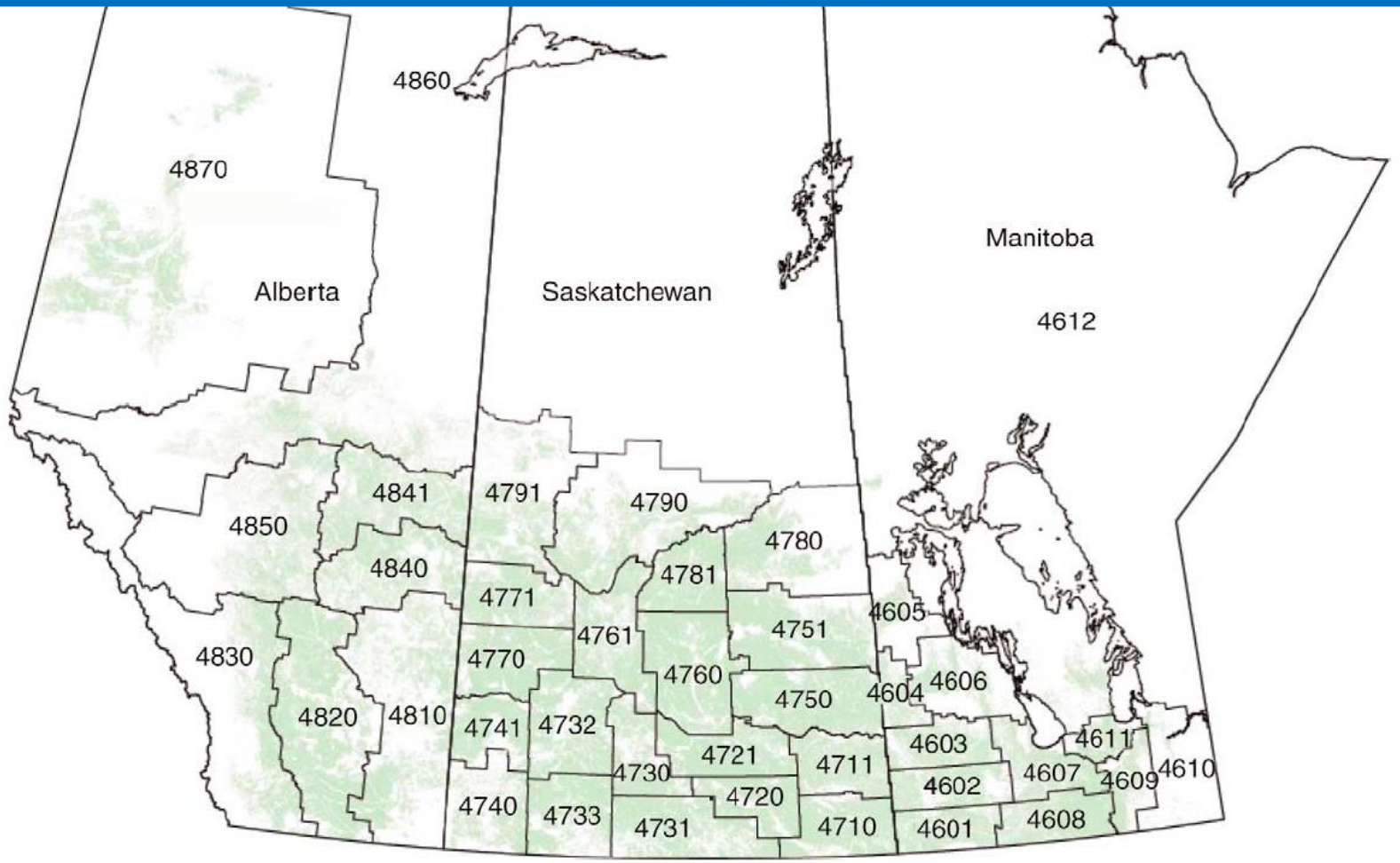


Figure 1. Agricultural crop districts in Saskatchewan from NO.4710 to NO.4791 on the Canadian prairies with shaded area showing cropland extracted from the map Land Cover for Agricultural Regions of Canada, circa 2000 (Agriculture and Agri-Food Canada 2013). Numbers are the codes of the Census Agricultural Regions.

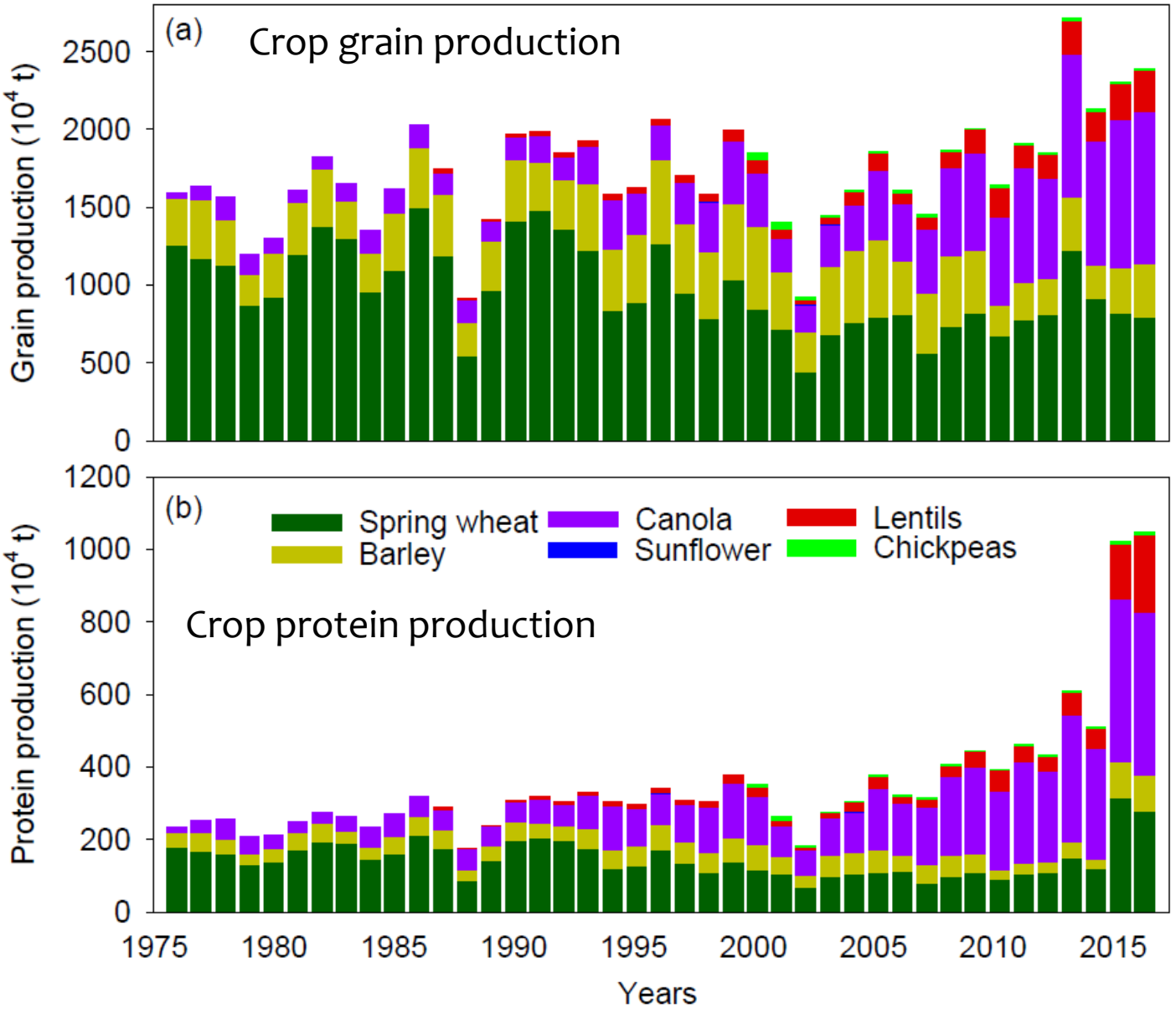
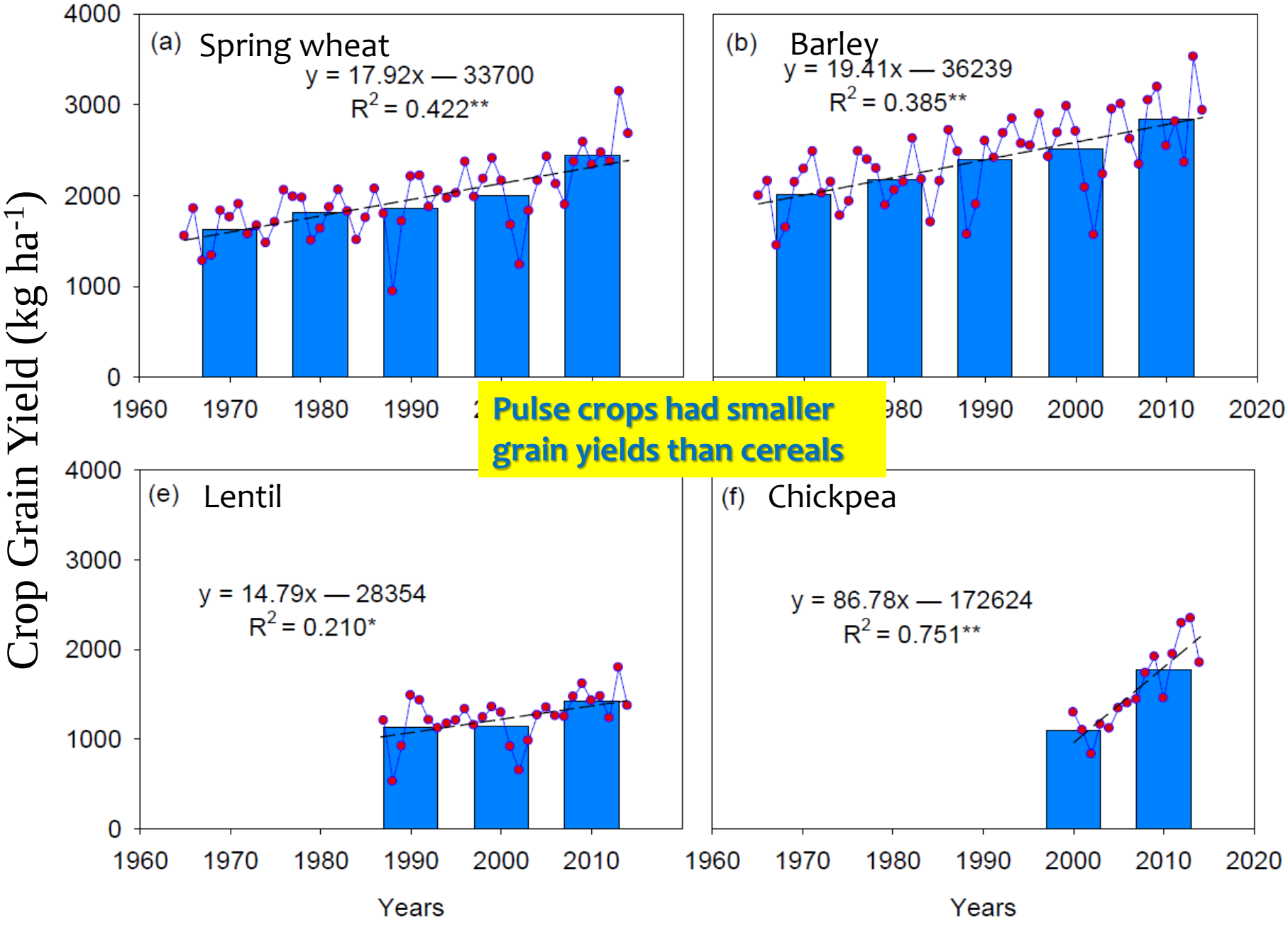
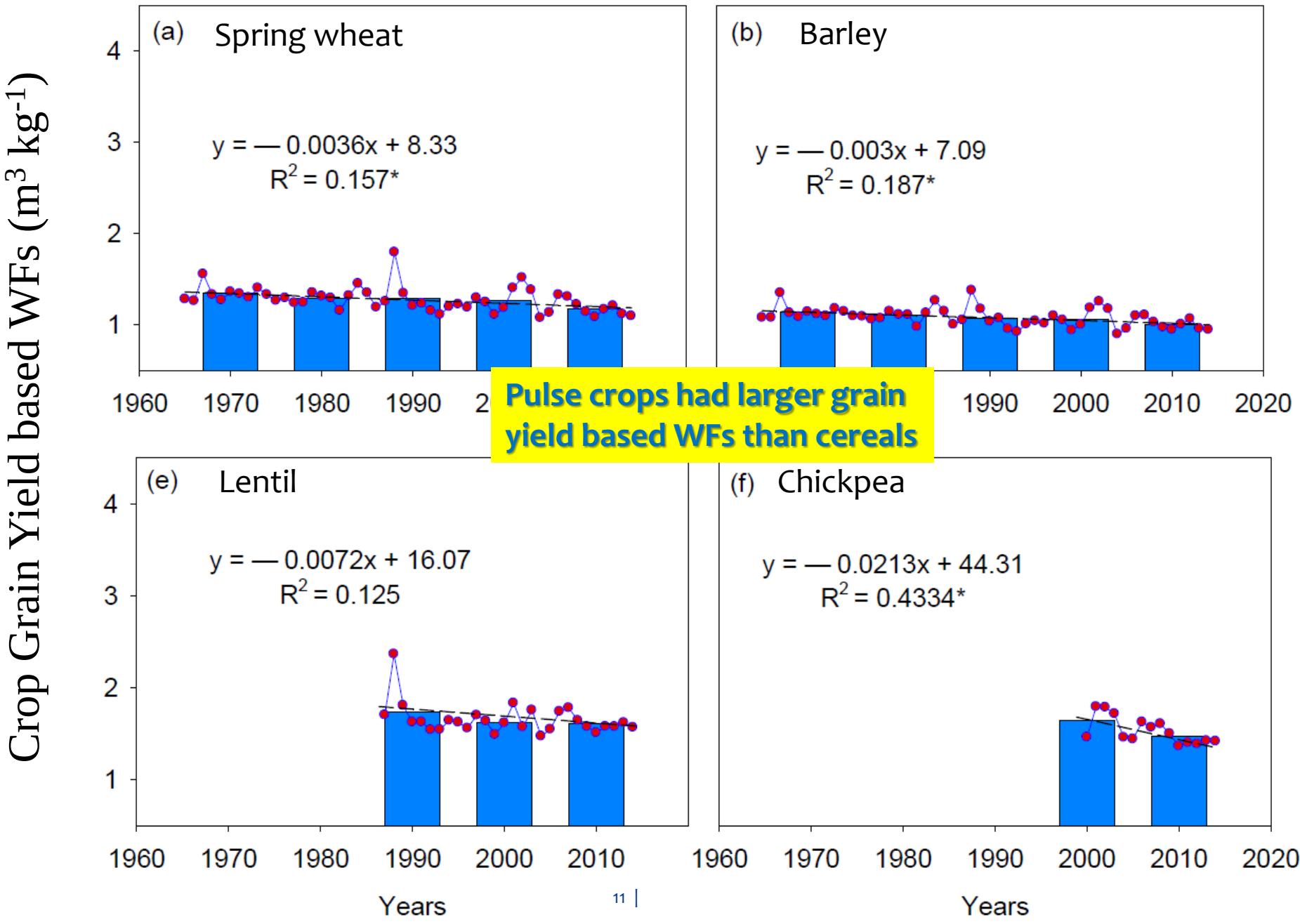
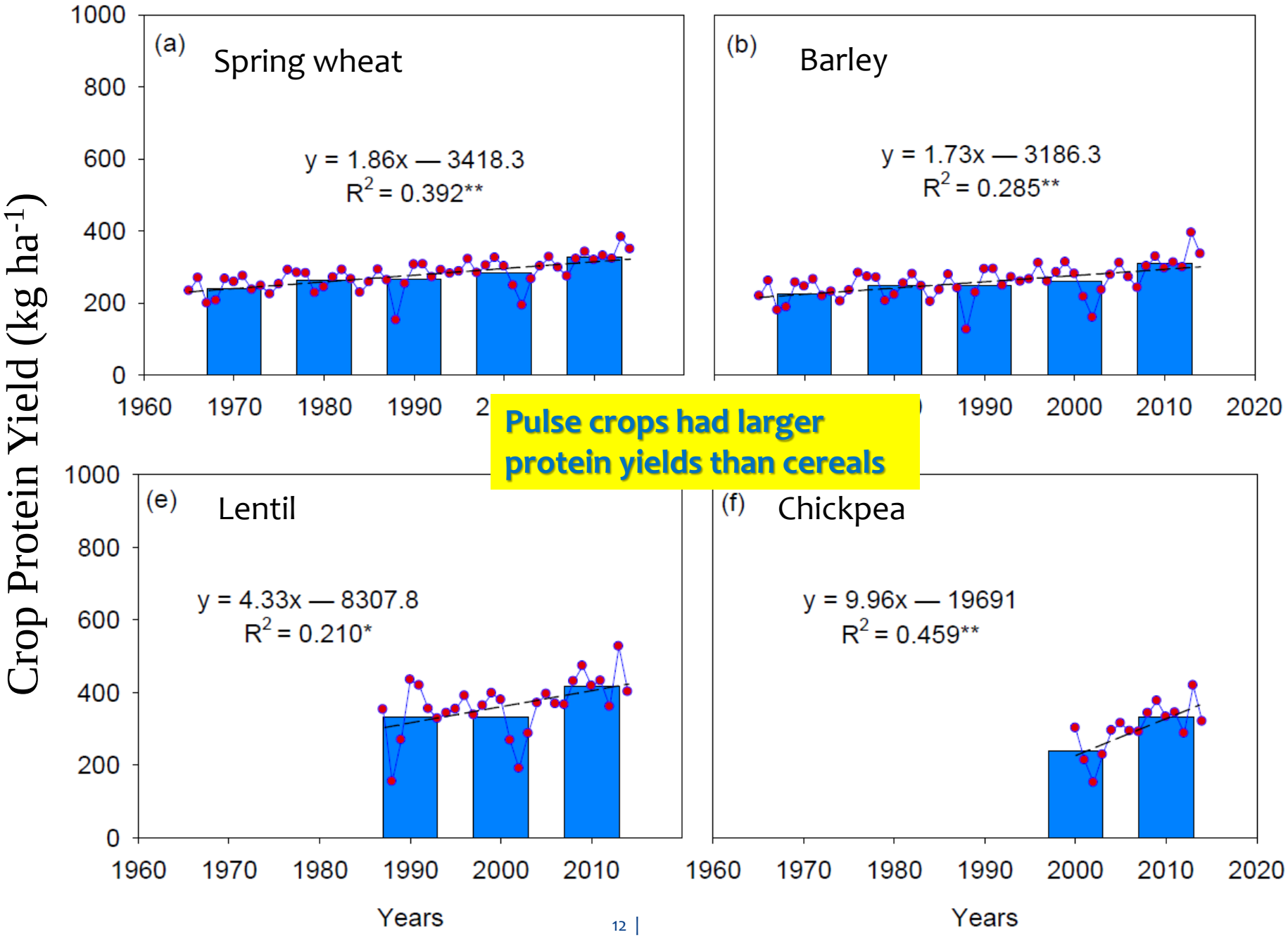
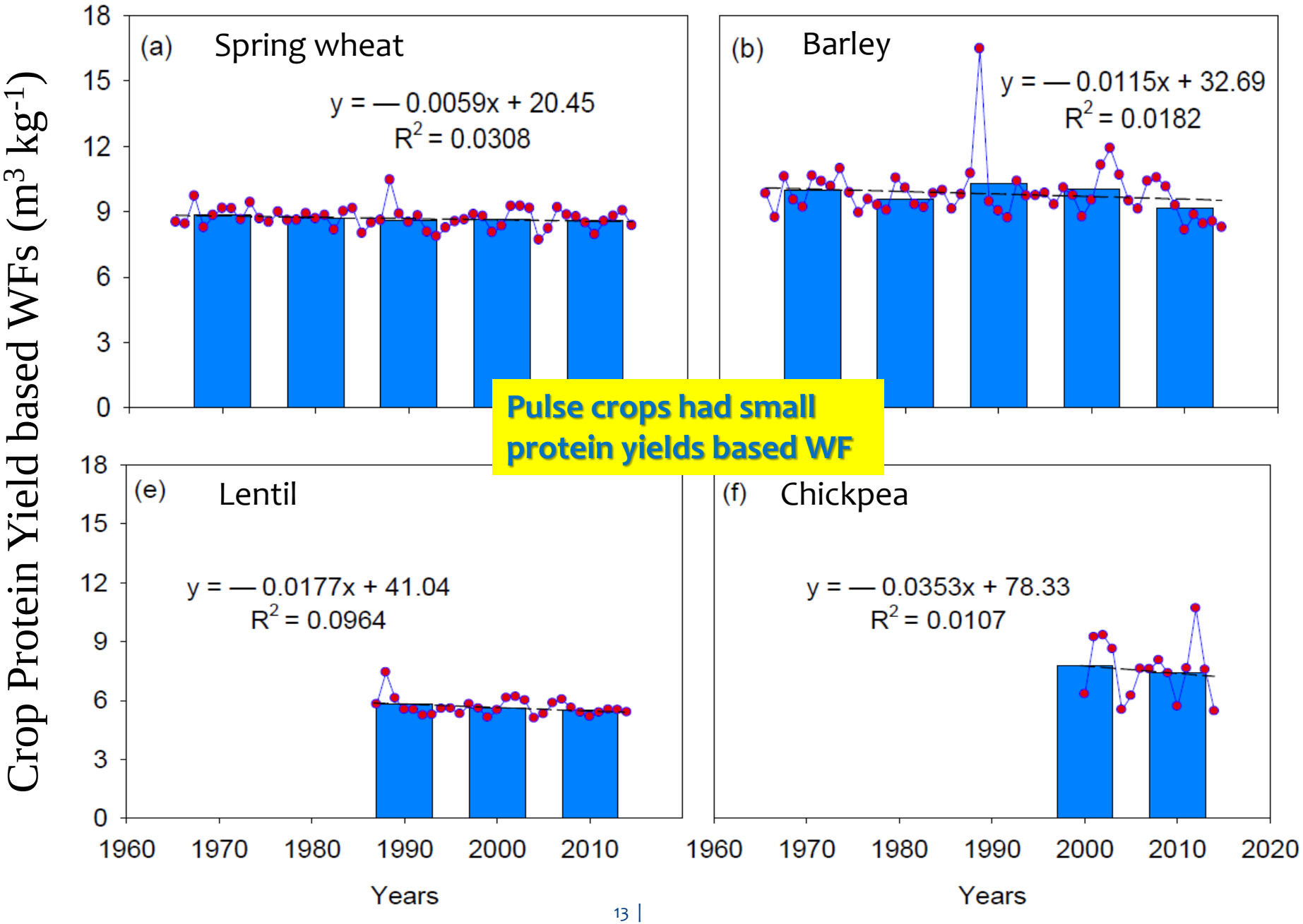


Figure 3. Inter-annual variability of total grain production, and protein production in Saskatchewan from 1976 to 2016


Crop Grain Yield (kg ha-1)
(a) Spring wheat
y = 17.92x — 33700
R2 = 0.422**
(b) Barley
y = 19.41x — 36239
R2 = 0.385**
Pulse crops had smaller grain yields than cereals
(e) Lentil
y = 14.79x — 28354
R2 = 0.210*
(f) Chickpea
y = 86.78x — 172624
R2 = 0.751**
0
1000
2000
3000
4000
1960
1970
1980
1990
2000
2010
2020
Years


Crop Grain Yield based WFs (m3 kg-1)
(a) Spring wheat
y = — 0.0036x + 8.33
R2 = 0.157*
(b) Barley
y = — 0.003x + 7.09
R2 = 0.187*
Pulse crops had larger grain yield based WFs than cereals
(e) Lentil
y = — 0.0072x + 16.07
R2 = 0.125
(f) Chickpea
y = — 0.0213x + 44.31
R2 = 0.4334*
1960 1970 1980 1990 2000 2010 2020
Years


Crop Protein Yield (kg ha-1)
(a)
Spring wheat
y = 1.86x — 3418.3
R2 = 0.392**
(b)
Barley
y = 1.73x — 3186.3
R2 = 0.285**
Pulse crops had larger protein yields than cereals
(e)
Lentil
y = 4.33x — 8307.8
R2 = 0.210*
(f)
Chickpea
y = 9.96x — 19691
R2 = 0.459**
0
200
400
600
800
1000
1960
1970
1980
1990
2000
2010
2020
Years


Crop Protein Yield based WFs (m^3 kg^{-1})
(a) Spring wheat
y = — 0.0059x + 20.45
R^2 = 0.0308
(b) Barley
y = — 0.0115x + 32.69
R^2 = 0.0182
Pulse crops had small protein yields based WF
(e) Lentil
y = — 0.0177x + 41.04
R^2 = 0.0964
(f) Chickpea
y = — 0.0353x + 78.33
R^2 = 0.0107
0
3
6
9
12
15
18
1960
1970
1980
1990
2000
2010
2020
Years

Controlling Factors for the yield increases

Scientific and technological progress index for a decade divided by the average yield in 1965–2014.

Years	Progress Index					
	Spring Wheat	Barley	Canola	Sunflower	Lentils	Chick Peas
1965–1974	1.000	1.000	1.000	\	\	\
1975–1984	1.116	1.084	1.147	\	\	\
1985–1994	1.143	1.165	1.220	1.000	1	\
1995–2004	1.233	1.245	1.236	1.173	1.013	1.000
2005–2014	1.364	1.295	1.524	1.515	1.166	1.547

Scientific and technological progress--- new crop cultivars and improved tillage and agronomic management

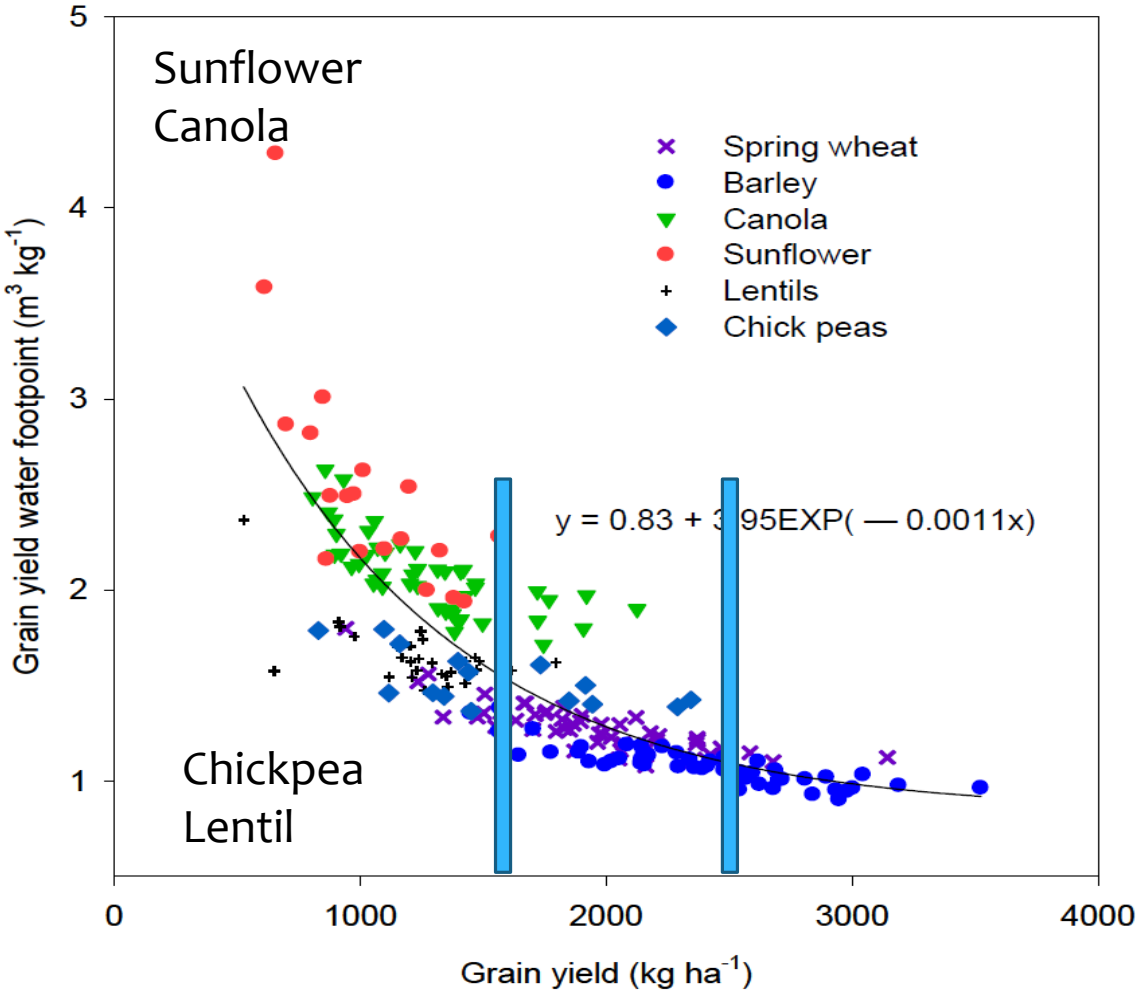
Controlling Factors

Path coefficient analysis between protein yield-based water footprints (WFs) and their influencing factors

Influence Factors	Spring Wheat	Barley	Canola	Sunflower	Lentil	Chickpea
Scientific and technological progress	−0.394	−0.807	−0.127	−2.257	−1.099	−0.413
Agricultural product price *	−0.311	−1.127	0.150	−2.314	−0.998	−0.238
Agricultural inputs	−0.443	−1.073	−0.147	−2.312	−1.151	−0.202
Population	−0.448	−1.088	0.270	−2.169	−1.103	−0.399
Annual precipitation	−0.785	−1.197	−0.302	−2.306	−1.436	−0.982
Seasonal precipitation	−0.773	−0.984	−0.293	−2.023	−1.135	−1.138
Average daily temperature	0.127	0.383	0.245	0.203	0.648	0.641

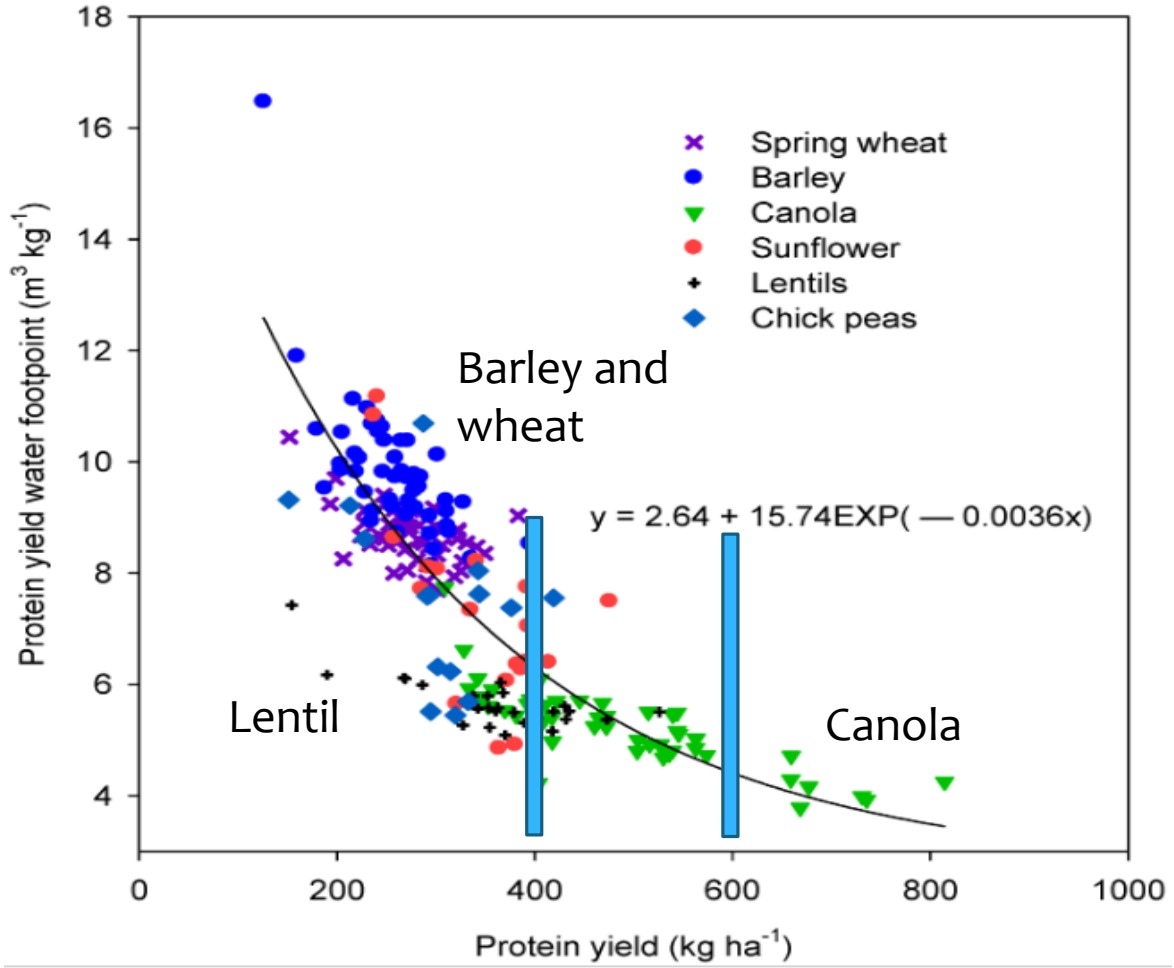
- Scientific and technological progress: new crop cultivars and improved tillage and agronomic management
- Agricultural inputs: agricultural machinery, chemical fertilizer, irrigation, and water saving technology

Grain yield-based WF Reduction Potential



Relationship between crop grain yield-based water footprints (WFs) and grain yields in Saskatchewan.

Protein-based WF Reduction Potential



Mild water stress is essential for initiating seed filling in pulse crops such as lentil

Pulses maintain the turgor pressure under drought conditions, facilitating the translocation of photosynthates to the grains

Relationship between crop grain yield-based water footprints (WFs) and grain yields in Saskatchewan.

Conclusion

- Grain yield-based WFs: pulses > cereal crops
- Protein yield-based WFs: pulses <cereal crops because of the high protein content of pulses
- The quantity and distribution of precipitation were key meteorological factors
- Scientific and technological progress and agricultural inputs evidently decreased the grain yield- and protein yield-based WFs of all crops
- Canola and spring wheat had the largest WF reduction potential for grain yield and protein based WFs, respectively

Recommendations

- Spring wheat and barley in wet years
- Chickpea and lentil in drought years
- Reduction of rotation protein-yield based WF if pulses are incorporated in rotation

Acknowledgement

- The research was funded by the Saskatchewan Pulse Growers [No. AGR1611].

Zhao et al., 2019. Temporal variability of water footprint for cereal production and its controls in Saskatchewan, Canada. The science of Total Environment. 660 : 1306–1316

Ding et al., 2018. Water Footprint for Pulse, Cereal, and Oilseed Crops in Saskatchewan, Canada. Water, 10:1609.

Thank You

Water Footprint Of A Product

- **Calculate the actual evapotranspiration rate**

$$ET_a = K_s \times K_c \times ET_0$$

- **Calculate the water stress factor based on actual yield**

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y \left(1 - \frac{\sum ET_a}{\sum CWR}\right)$$

- **Calculate the water footprint from the ratio of ET_a to Y_a**